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DISCOVERY

Hydrogeochemical Evaluation of Groundwater for Irrigation Purpose in Ekaeru Inyimagu and its Adjoining Area, Ebonyi State, Nigeria

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ABSTRACT

The research was aim at accessing the groundwater suitability for irrigation purpose. A total of six groundwater sample was collected and analysed following APHA 1995 standard. Hydrochemical parameters analyzed include: pH, Electrical conductivity (Ec), Total Dissolved Solid (TDS), Magnesium (Mg), Calcium (Ca), Potassium (K), Sodium (Na), chloride (Cl) and Bicarbonate (HCO3). Irrigation indices was used to evaluate the suitability of groundwater for irrigation use. Results from Piper diagram revealed that the dominant ionic species in the study area is Cl. Results showed that Ec ranges from (126.24 to 752.43 µS/cm), TDS ranges from 90.32 to 855.27 mg L-1, TH ranges from 41.00 to 95.00mg/L-1. Results obtained from irrigation indices revealed that SAR ranges from 0.28 to 0.78, MAR ranges from 11.7 to 536.8%), PI ranges from 0.40 to 1.00%, Kelly Ratio ranges from 0.14 to 0.39, RSBC ranges from -1.43 to 0.6, Na% ranges from 14.00 to 39.02% and SSP ranges from 0.28 to 0.78%. Based on estimated value from MAR

sample locations EBY/01, EBY/ 02, EBY/03, EBY/03 were considered unfit for irrigation. While for sample locations EBY/04 and EBY/05 was considered suitable for irrigation. EBY/06 is considered fairly suitable for irrigation.

Keywords: Groundwater, Asu-River Group, Irrigation, Suitability, Abakaliki

1. INTRODUCTION

Groundwater is one of the major natural resources that is needed for sustainable development in facet of life. Its importance cannot be underestimated as it is needed for human and plants upkeep. Water is considered necessary for plants growth and better yield. Reports has it that large percentage of the inhabitant of study area are petty farmers that depend on their farm produce for livelihood. Although the farmer have intention of extending their farming from small scale farming to large scale, various factors tend to hidden them from achieving their goals, one of such is water. The study area is faced with serious water scarcity problem during the dry season and even the little water source available are polluted and considered unsuitable for domestic and other usage (Ezeh, et al., 2016; Eyankware, et al., 2016a; Obasi, et al., 2015). Various factors are responsible for groundwater pollution according to Moses, et al., (2016) such factor are; leachate from landfill sites, irrigation return flow and domestic and industrial wastes. Moreso, globally groundwater has been on high demand for agriculture (Reza, et al., 2013; Islam, et al., 2013; Sreenivasa, et al., 2015; Jain, et al., 2012) Islam, et al., (2013) were of the view that availability of groundwater for irrigation has contributed to manifold increase in crop productivity in Bangladesh. But that is not case in Nigeria as most research on groundwater is aimed towards its quality for drinking and domestic use. In past years research has been focused on quality of groundwater for domestic use within the study area (Ezeh, et al., 2016; Eyankware, et al., 2016a; Obasi, et al., 2015). But research on assessment of water quality for irrigation is limited within south eastern Nigeria. The research is aimed at determining the quality of groundwater for irrigation. This paper is aim at assisting the state government and non-governmental organization in meeting sustainable development goal on groundwater quality for irrigation use.

Location/Accessibility

Geographically, the study area is located between latitude 6^0 15' N - 6^0 22'N and longitude 8^0 05'E - 8^0 10' E. The Ekaeru Inyimagu is located in Ebonyi State, southeastern part of Nigeria. The area is accessible through network of roads like Nwagu, Agbaja, Obugha Amachi and Ekaeru Inyimagu. (Fig.1).

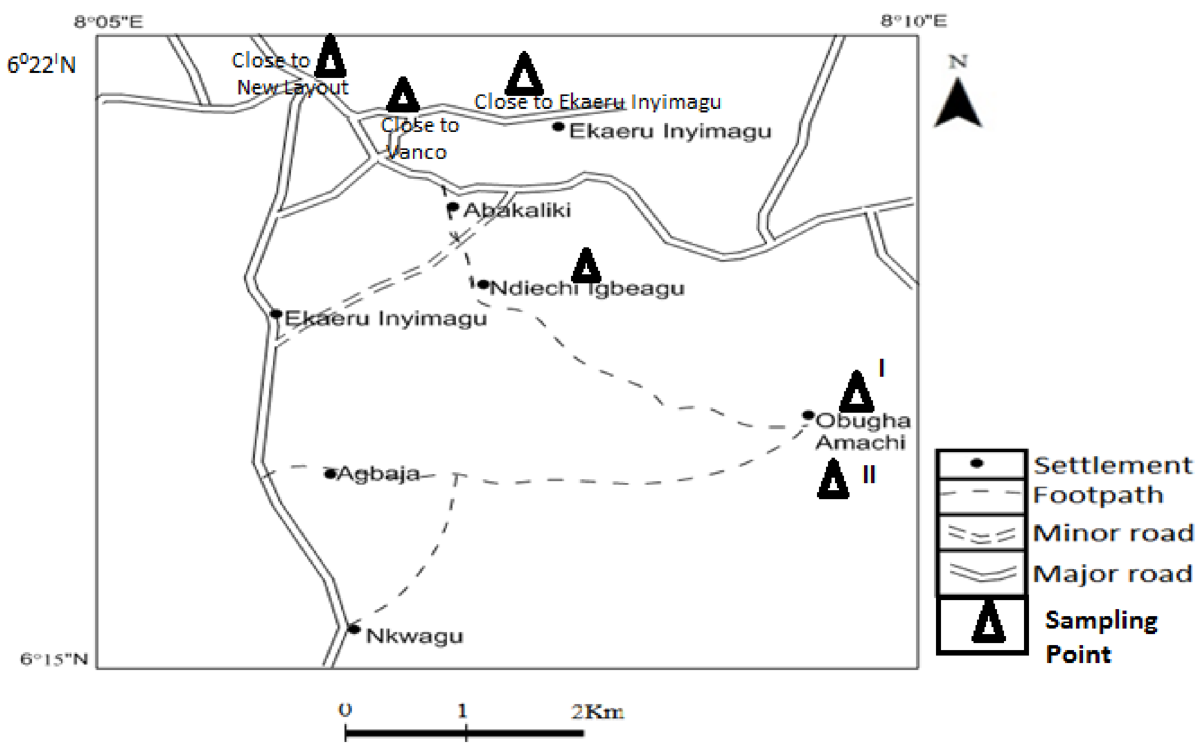

Fig.1: Accessibility Map of Study Area Showing Sampled points.

Geology of the study area

The study area is of the Lower Benue Trough (Fig.2). The Lower Benue Trough was described by Murat (1972) and Hoque (1977) using the concept of three tectonic sedimentary cycles. Nwajide, (2013) reported that three such cycles of marine transgressions and regressions took place within the Albian to the Coniacian. Murat, (1972) was of the view that the first recorded marine transgression of the Benue Trough exist in the middle Albian period, with the deposition of the Asu River Group in the Lower Benue Trough. Reyment, (1965) pointed out that Asu River Group sediments are predominantly shales, siltstone, sandstone and limestone facies as well as extrusives and intrusives. The Asu River Group has an average thickness of about 2000m and uncomfortably overlies the Precambrian Basement (Benkhelil, et al., 1989). Reyment, (1965) further pointed out that folding and fracturing occurred within the Santonian tectonic phase, thereby giving rise to chains of anticlines and syncline known as the Abakaliki Anticlinorium. Farrington, (1952) further reported that fracture trend that host lead-zinc forming in the southern Benue Trough were in northwest to southwest and north-northwest to southeast direction. Studies by Agumanu, (1989) revealed that the Asu River Group sediment were splitted into the Abakaliki and Ebonyi Formation and that the Abakaliki Formation is predominantly underlain by dark grey colored shale and indurated in most locations, but some other locations was reported fissile. Previous scholar reported outcrop of intrusive rock within the area, such outcrop was notice within Onu-ebonyi, Ogbaga, Juju Hill, Strabag quarry, Sharon mines and Azu-iyiokwu River (Nwajide, 2013).

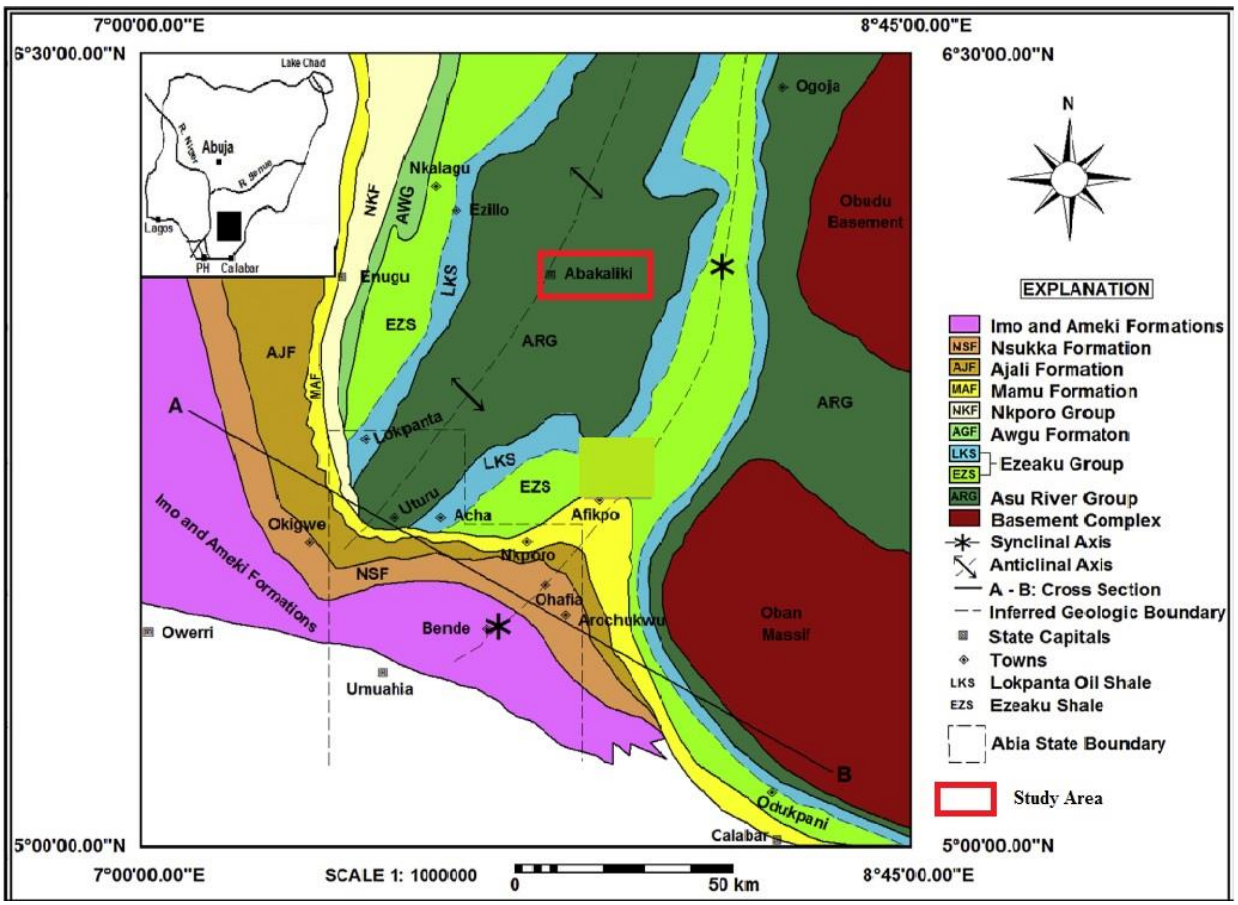

Fig. 2: Regional Geological Map of the Southern Benue Trough. Source: (Modified after Okoro, et al., 2016).

Hydrogeology

Studies by Cocker (1995); Hook (2005); Pazand, et al., (2011) showed that hydrochemistry of surface and groundwater are principally controlled by the rocks and sediments through which these waters flow through.

Previous information on geochemistry of water of a given area is vital in understanding the current hydrochemical of the same area for proper planning and monitoring of its water quality. On a general note groundwater within the Asu River Group is influenced by several factors such as thickness, lithology and structure of the rock formation.

2. METHODOLOGY

Sample Collection and Analysis

Six groundwater samples was collected from boreholes and hand-dug wells (Figure 1). These samples were labelled EBY/01- EBY/06 as shown in Table. 1. The water sample were analyzed for physical and chemical parameters. A 500ml polythene-free bottles was used for sample collection. Sampling bottles were washed and thoroughly rinsed with distilled water. They were also vigorously rinsed at the sample collection point with water from the sources of collection. 2-3 drops of dilute hydrochloric acid was added to avoid metal oxidation and was subsequently caped and labeled. The water samples was stored and immediately transported to the laboratory few hours after sample was collected. The water samples were persevered and transported to the laboratory for analyzed within few hours of sample collection. Physical parameters were determined in situ with measuring kits standard methods. pH of the water samples were measured by electrometric method using laboratory pH meter according to America Public Health Association (APHA) 2005 guideline, Model DDS-307. Mercury thermometer was used to determine the temperatures of the water samples, METRO HM644 conductivity meter was used to measure electrical conductivity, turbidity of the samples were measured using turbidity meter. Major ions (cations and anions) were determined using their various standard methods. Cation were analyzed using Fast sequential Atomic Absorption Spectrophotometer, Varian 240 AA was used. Anions were analyzed using Ultra Violet spectroscopy, PV 300 opel was used. Minor/trace ions were determined by titration. Heavy metal analysis was done using varian AA240 Absorption spectrophotometer (ASS) according to APHA (1995) guidelines.

Table 1: Result of Analyzed Physical and Chemical Parameters

PARAMETERS	**EBY/01** Obugha Amachi I	**EBY/02** Obugha Amachi II	**EBY/03** Ndechi Igbeagu	**EBY/04** Sharon Junction	**EBY/05** New Layout	**EBY/06** Water Works
$_{p}$H	8.01	7.43	7.05	6.7	6.08	7.5
TDS (mg L^{-1})	90.32	623.54	115.44	855.27	617.34	113.95
E.C μ/Scm	325.08	148.65	752.43	524.7	282.65	126.24
SO_4^{2-} (mg L^{-1})	8.43	14.05	6.09	9.56	6.76	14.54
HCO_3^- (mg L^{-1})	43	78	22.04	15.32	28.45	14.34
K^+(mg L^{-1})	1.06	0.02	1.98	2.18	6.00	1.40
Mg^{++} (mg L^{-1})	8.45	10.28	12.43	2.76	9.23	1.65
Na^+ (mg L^{-1})	7.42	10.01	6.07	12.65	9.32	8.94
Ca^{++} (mg L^{-1})	4.04	13.44	16.65	33.81	6.83	28.54
Cl^- (mg L^{-1})	78	213	35	16.6	101	154
NO_3^-	4.32	3.92	5.54	4.54	2.00	6.07

Statistical analyses

Relevant statistical packages (SPSS Version 17, Microsoft Excel 2007 Statistical Tool Pack) was used to analyze the data obtained. Descriptive statistics were some of the analyses carried out in this study.

3. RESULT AND DISCUSSION

Hydrogeochemical Facies

Fig. 3 and 4 shows Piper and Schoeller diagrams findings revealed that sample EBY/01 is of Mg- Cl - HCO_3 water type, samples EBY/02 is of Cl - HCO_3, sample EBY/03 is of Mg- Ca –Cl water type, samples EBY/04, is of Ca-Na- Cl, sample EBY/05 is of Mg-Cl water type, while samples EBY/06 is of Ca-Cl. The dominat ionic species in the study area is Cl from the Piper plot.

Assessment of groundwater using irrigation indices

Water of good quality is considered necessary for irrigation. Just as every water is considered unsuitable for human use, in the same way, every water is considered unsuitable for plant. Nata, et al., (2011) reported that water that is highly contaminated, tends to hidden the growth of plants, in most situation considered unfit for irrigation. Groundwater quality was evaluated using irrigation indices such as: SSP, MAR, Na %, SAR, KR and PI.

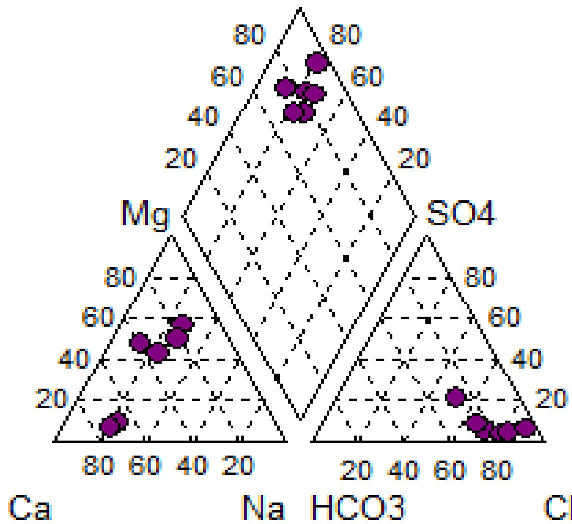

Figure 3: Piper Trilinear diagram for water characterization of the study Area.

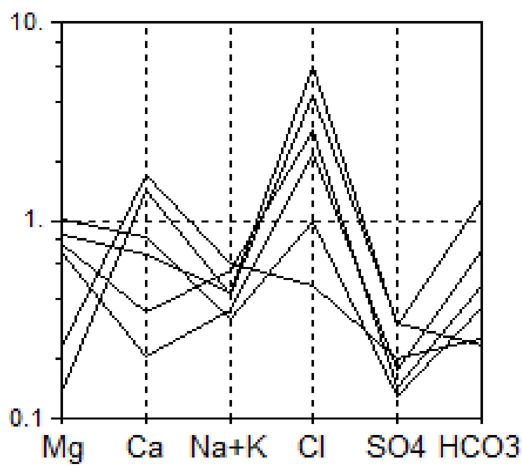

Figure 4: Schoeller semi logarithmic diagram showing the hydrogeochemical attribute.

Magnesium Adsorption Ratio (MAR)

Joshi et al, (2009) was of the view that major element for qualitative assessment of water quality for irrigation is magnesium and they further pointed out that Ca and Mg maintain a state of equilibrium in most water, Soil salinity has adverse affect on crop, high concentration of soil salinity may be attributed to high magnesium concentration in soil. The value of MAR ranges from 11.71 to 536.84 with mean value of 71.83. Based on the value of MAR sample EBY/01, EBY/ 02, EBY/03, EBY/03 is not fit for irrigation. While for sample EBY/04 and EBY/05 is considered suitable for irrigation. EBY/06 is considered fairly suitable for irrigation (Table 3). High content of magnesium in soil is considered to have effect on crop yield as the soil become more alkaline. MAR less than the acceptable limit of 50 (Ayers and Westcot, 1994). The Magnesium Adsorption Ratio was calculated using the following equation (Raghunath, 1987):

$$\textbf{MAR} = \frac{Mg^{++} \times 100}{Mg^{++} + Ca^{++}} \qquad \text{(eqn 1)}$$

Where all ionic concentration are expressed in meq/L.

Table 2: Analyzed Physical and Chemical Parameters

PARAMETERS	EBY/01 Obugha Amachi I	EBY/02 Obugha Amachi II	EBY/03 Ndechi Igbeagu	EBY/04 Sharon Junction	EBY/05 New Layout	EBY/06 Water Works
SO_4^{2-} (meq/L)	0.17	0.29	0.12	0.19	0.14	0.30
HCO_3^- (meq/L)	0.70	1.27	0.36	0.25	0.46	0.23
K^+(meq/L)	0.02	0.00	0.05	0.05	0.15	0.03
Mg^{++} (meq/L)	0.69	0.84	1.02	0.22	0.75	0.13
Na^+ (meq/L)	0.32	0.43	0.26	0.55	0.40	0.38
Ca^{++} (meq/L)	0.20	0.67	0.83	1.68	0.34	1.42
Cl^- (meq/L)	2.20	6.00	0.98	0.46	2.84	4.34
NO_3^- (meq/L)	0.06	0.06	0.08	0.07	0.03	0.09

Note: Concentration are in **meq/L**

Table 3: Value of Irrigation Parameters

SAMPLED LOCATION	RSBC	MAR	TH	SAR	SP	SPP	SAR	PI
EBY/01	0.5	147.6	41	0.39	39.02	28.07	0.78	1.00
EBY/02	0.6	494.7	75.5	0.28	28.47	22.16	0.57	0.79
EBY/03	-1.32	536.84	92.5	0.14	14.05	12.32	0.28	0.40
EBY/04	-1.43	20.54	95	0.30	28.94	22.44	0.57	0.42
EBY/05	0.1	74.07	54.5	0.36	36.69	26.84	0.74	0.71
EBY/06	-1.19	11.71	72.5	0.24	24.51	19.68	0.49	0.44
Minimum	-1.43	11.71	41	0.14	14.05	12.32	0.28	0.4
Maximum	0.6	536.84	95	0.39	39.02	28.07	0.78	1
Mean	-0.45	214.24	71.83	0.28	26.81	21.91	0.57	0.62
STDEV	0.95	238.89	21.11	0.08	8.97	5.64	0.18	0.24

Soluble sodium percentage (SSP)

The values of SSP less than 50 indicates good quality of water and higher values shows that the unacceptable quality of water for irrigation (USDA, 1954). SSP value ranges from 0.28 to 0.78 with mean value of 0.18 (Table 3). The water samples are suitable for irrigation purpose because SSP value is less than 50 (Table 3).

SSP calculated by using Todd, (1980).

$$SSP = \frac{Na^+ \times 100}{Ca^{++} + Mg^{++} + Na^+} \qquad \text{(eqn 2)}$$

Where all ionic concentration are expressed in meq/L.

From the Wilcox diagram EBY/ 01 to EBY/05 can classified under excellent to permissible (Fig: 5a). This implies that the samples are fit for irrigation purpose based Wilcox SSP diagram.

Sodium Percentage (Na %)

Sodium percentage is an important factor used in suitability of water for irrigation. Sodium hazard is usually evaluated using Na%. The value of Na% ranges from 14.05 to 39.02 with mean value of 26.81 (Table 3). Na % was calculated by using (Doneen, 1964) formula:

$$Na\,\% = \frac{Na^{+} \times 100}{Ca^{++} + Mg^{++}} \qquad \text{(eqn 3)}$$

Where all ionic concentration are expressed in meq/L.

The Wilcox, (1955) diagram relating sodium percentage and electrical conductivity shows that 90% of the groundwater samples fall within excellent to good (EBY/01, 02, 04, 05 and 06). While EBY/03 fall within good to permissible as shown in Fig.5b.

Permeability Index (PI)

Permeability index is considered to be an important criterion on accessing water quality for irrigation. The value of PI ranges from 0.40 to 1.00 with mean value of 0.62 (Table 3). Based on value range of PI it is fit for irrigation purpose (Table 3). PI is classified under Class I (>75% permeability), Class II (25-75% permeability) and Class III (<75% permeability) orders. Class I and Class II waters are categorized as good for irrigation and Class III waters are unfit with 25% of maximum permeability, EBY/01 and 06 is classified under Class I, while EBY/02, 03, 04 and 05 are classified under Class II. (Fig. 5c).

$$\textbf{PI} = \frac{\sqrt{Na^{+} + HCO_3^{-}}}{Ca^{++} + Mg^{++} + Na^{+}} \qquad \text{(eqn 4).}$$

Where all ionic concentration are expressed in meq/L.
As proposed by Domenico, et al., (1990).

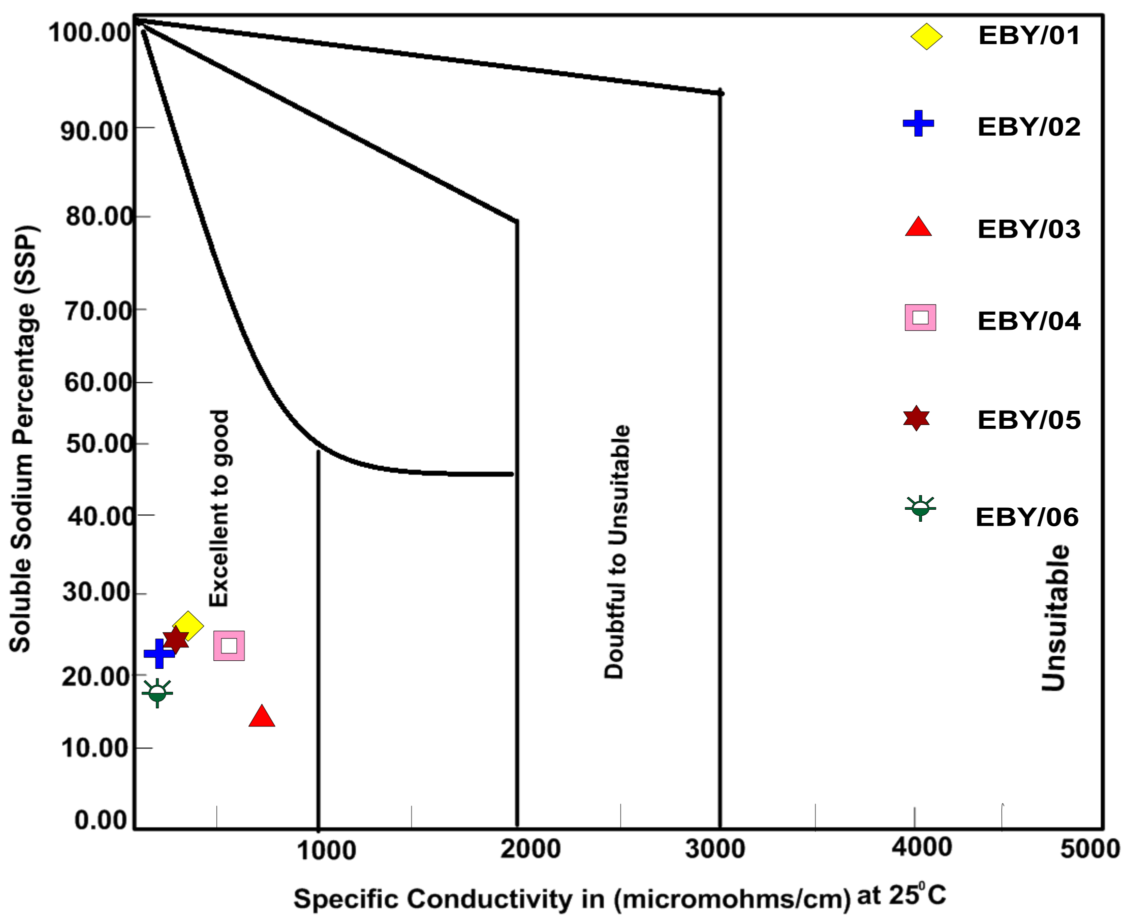

Figure 5a: Wilcox Diagram for groundwater in the study Area.

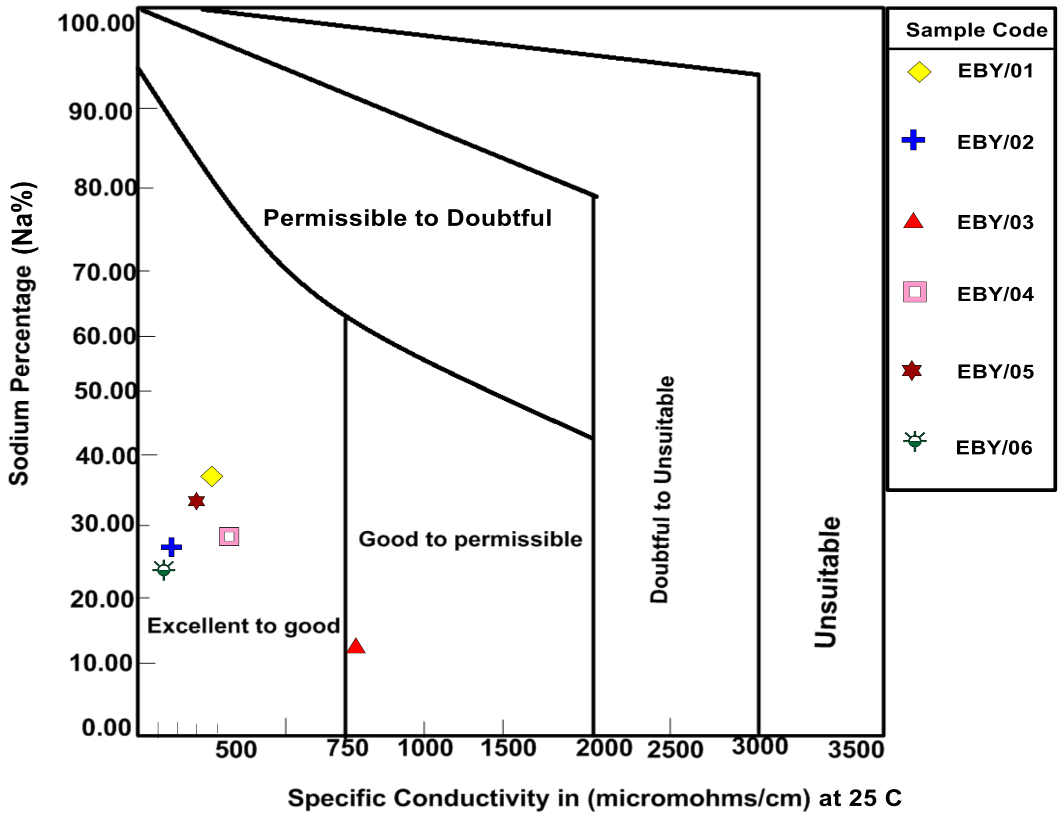

Figure 5b: Rating of groundwater samples on the basis of electrical conductivity and percent sodium (after Wilcox, 1955).

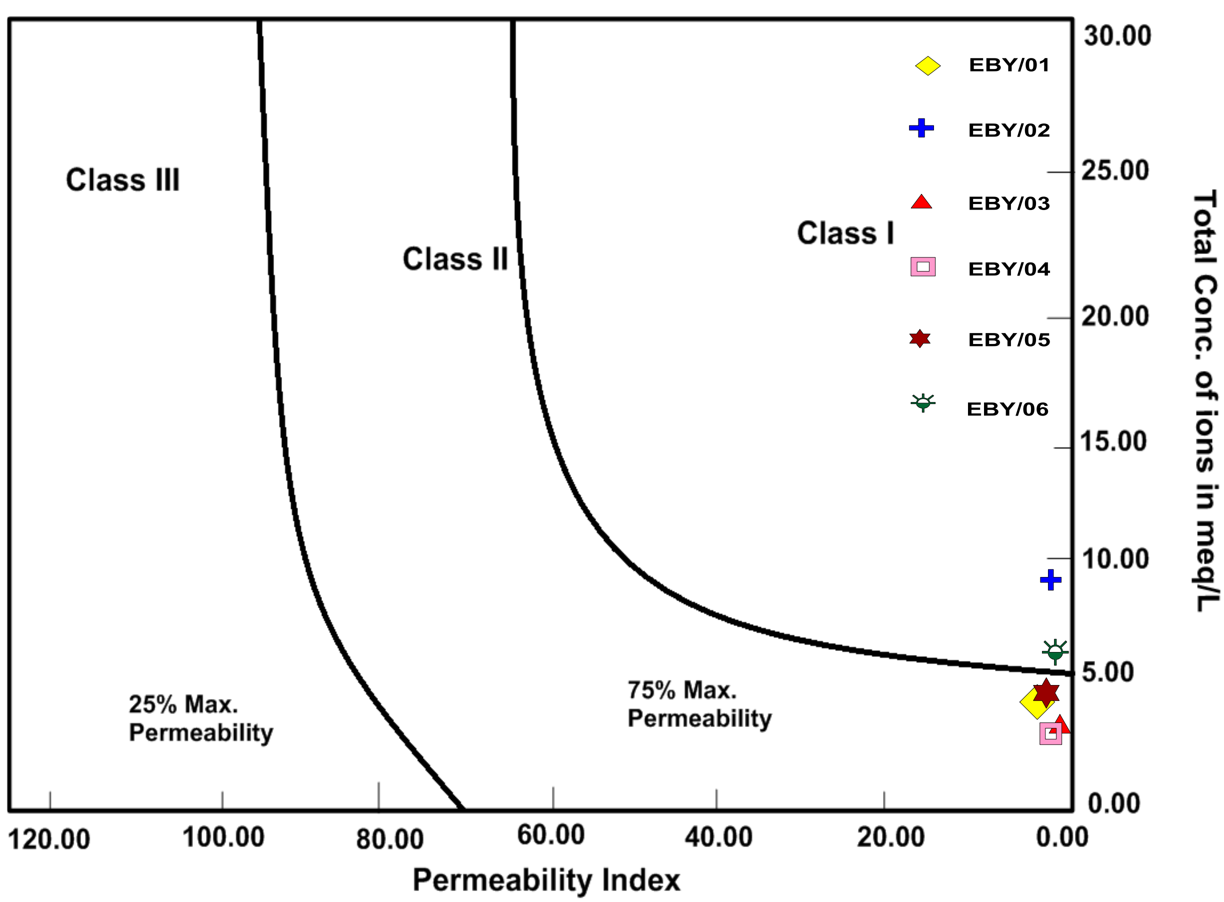

Figure 5c: Doneen's, (1964) Chart for P.I. values of groundwater.

Total Hardness (TH)

TH value ranges from 41 to 95 with mean value of 71.83 (Table 3). Results revealed that groundwater were classified as soft and moderately hard water based on Sawyer, et al., (1967) see Table. 3.

$$TH = (Ca^{++} + Mg^{++}) \times 50 \qquad \text{(eqn 5).}$$

As proposed by Raghunath, (1987)

Table 1: Groundwater Classification Based on Total Hardness (Sawyer, et al., 1967)

Total hardness as $CaCO_3$(mg/l)	Water Class	Number of Samples	Percentage of sample (%)
<75	Soft	3 (EBY/01,05 and 06)	38.97
75 – 150	Moderately Hard	3(EBY/02, 03 and 04)	61.02
150 – 300	Hard	-	
>300	Very Hard	-	

Residual Sodium Bi-carbonate (RSBC)

Residual sodium bicarbonate (RSBC) exists in irrigation water when the HCO_3^- concentration supercedes the Ca concentration of the water. In a situation where RSBC in water is high (>2.5meq/L). Long usage of water for irrigation could amount to accumulation of Na in soil. It may lead to the following (i) have direct effect on crops, (ii) trigged soil salinity (EC) and associated poor plant growth, and (iii) air and water movement is hindered by clay/silt in soil and loss of soil structure occur through clogging (SAI, 2010; Naseem, et al., 2010). The RSBC value of the study area is between -1.43 to 0.6 with mean -0.45 (Table 3) indicating good quality for irrigation purpose.

$$RSBC = HCO_3^- - Ca^{++} \qquad \text{(eqn 6).}$$

As proposed by Gupta and Gupta (1987)

Kelly Ratio (KR)

Karanth, (1987) stated that when KR is equal to or < than 1 it implies that the water is of good quality for irrigation whereas values > 1 suggest that water is considered unsuitability for agricultural purpose due to alkali hazards. The value of KR ranges from 0.14 to 0.39 with mean value of 0.28. Based on the value the water is fit for irrigation purpose (Table 3).

$$\mathbf{KR} = \frac{Na^+}{Ca^{++} + Mg^{++}} \qquad \text{(eqn 7).}$$

As proposed by Kelly, (1963)

Sodium Adsorption Ratio (SAR)

SAR is an easily measured property that gives information on the comparative concentrations of Na^+, Ca^{++}, and Mg^{++} in the water samples (Talabi, et al., 2014). The SAR takes into consideration the fact that the adverse effect of sodium is moderated by the presence of calcium and magnesium ions. Munshower, (1994), Brady, (2002) stated that when critical soil problem arise when SAR is > 12 to 15 in such situation it may be difficult for soil to absorb water. The value of SAR ranges from 0.28 to 0.78 with mean value of 0.57 (Table 3). Based on this the value of SAR is fit for irrigation purpose.

$$SAR = \frac{Na+}{\sqrt{\frac{(Ca^{++} + Mg^{++})}{2}}} \qquad \text{(eqn 8).}$$

As proposed by Raghunath, (1987)

Electrical Conductivity (EC)

Electrical conductivity is a good measure of salinity hazard to crops as it reflects the TDS in groundwater (Sawid, et al., 2015). The value of EC ranges from 126.24 to 752.43 μS/cm.

Table 2: Classification of Groundwater Based on EC

Salinity Hazard (Class)	EC μ/Scm	Sampling Points	
Excellent (C1)	<250	EBY/02 and 06	(2)
Good (C2)	250 -750	EBY/01, 04 and 05	(3)
Doubtful (C3)	750 -2250	EBY/03	(1)
Unsuitable (C4)	>2,250		

From the US Salinity diagram EBY/ 01, 04 and 05 can group in C2 (Good) based on Fig.3, while EBY/02 and 06 are group into C1 (Excellent) Fig. 3d. And finally EBY/03 is group into C3 (Doubtful) based on CGWB and CPCB (2000), (Fig.5d and Table 2 and 5).

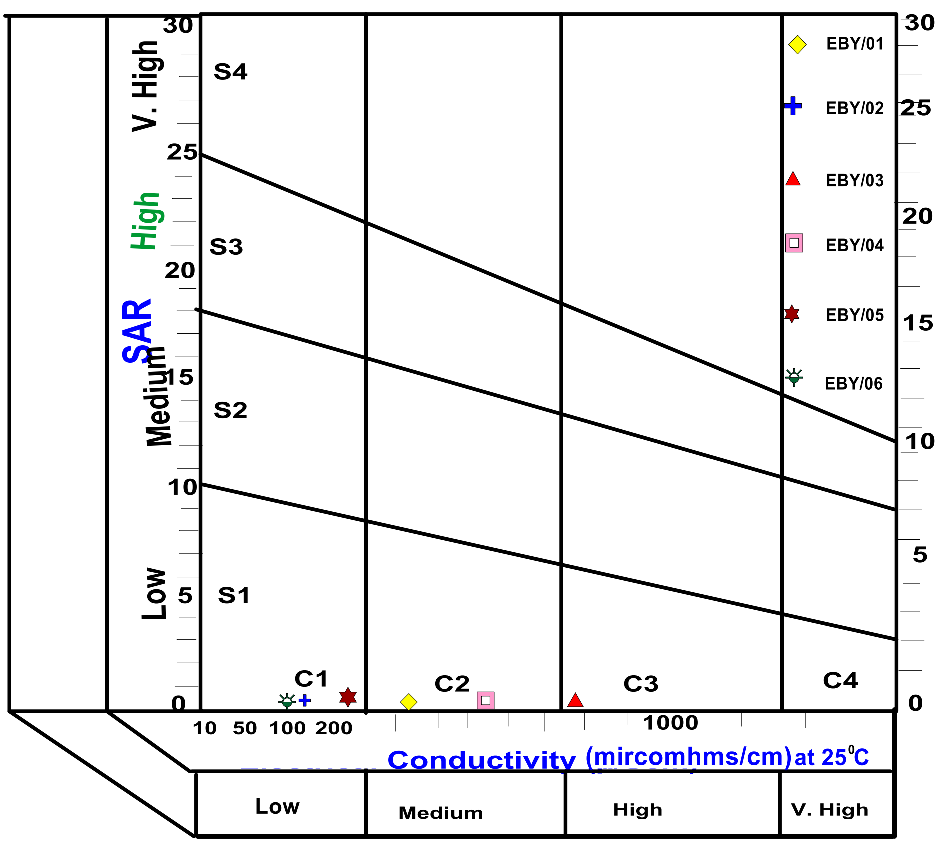

Fig. 5d: Classification of Groundwater based on US salinity diagram.

Where C1 = Excellent, C2 = Good, C3 =Doubtful, C4 = Unsuitable, S1 = Excellent, S2 = Good, S3 =Doubtful, S4 = Unsuitable.

Table 4: Table Showing Sampling Points

Co-ordinate	Sampling Code	Sampling Location
N8^{0}09^{I} 57^{II}. E 006^{0} 17^{1}13^{II}	EBY/01	Obugha Amachi I
N8^{0}09^{I} 57^{II}. E 006^{0}16^{1} 51^{II}	EBY/02	Obugha Amachi II
N8^{0}08^{I} 09^{II}. E 006^{0}18^{1} 24^{II}	EBY/03	Ndechi Igbeagu
N8^{0}06^{I} 51^{II}. E 006^{0}21^{1} 10^{II}	EBY/04	Close to Vanco Junction
N8^{0}06^{I} 15^{II}. E 006^{0}21^{1} 45^{II}	EBY/05	Close to New Layout
N8^{0}07^{I} 03^{II}. E 006^{0} 21^{1} 44^{II}	EBY/06	Close to Ekaeru Inyimagu

Table 5: Guidelines for evaluation of irrigation water quality. Source: Modified after CGWB and CPCB (2000)

Water Class	Na%	SAR	MAR	PI	SSP	KR	EC (µS/cm)
Excellent	<20	<10	<50	<80	50	<1.0	<250
Good	20-40	10-18	<50				250-750
Medium	40-60	18-26		80-100			750-2250
Bad	60-80	>26	>50	100-120			2250-4000
Very Bad	>80	>26	>50			>1.0	>4000

Fig. 6 showed that groundwater samples fell under the Alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions for more on this see Chadba, (1999). Water that fell within type 7 is considered to be permanent hard and does not deposit residual sodium carbonate in irrigation use.

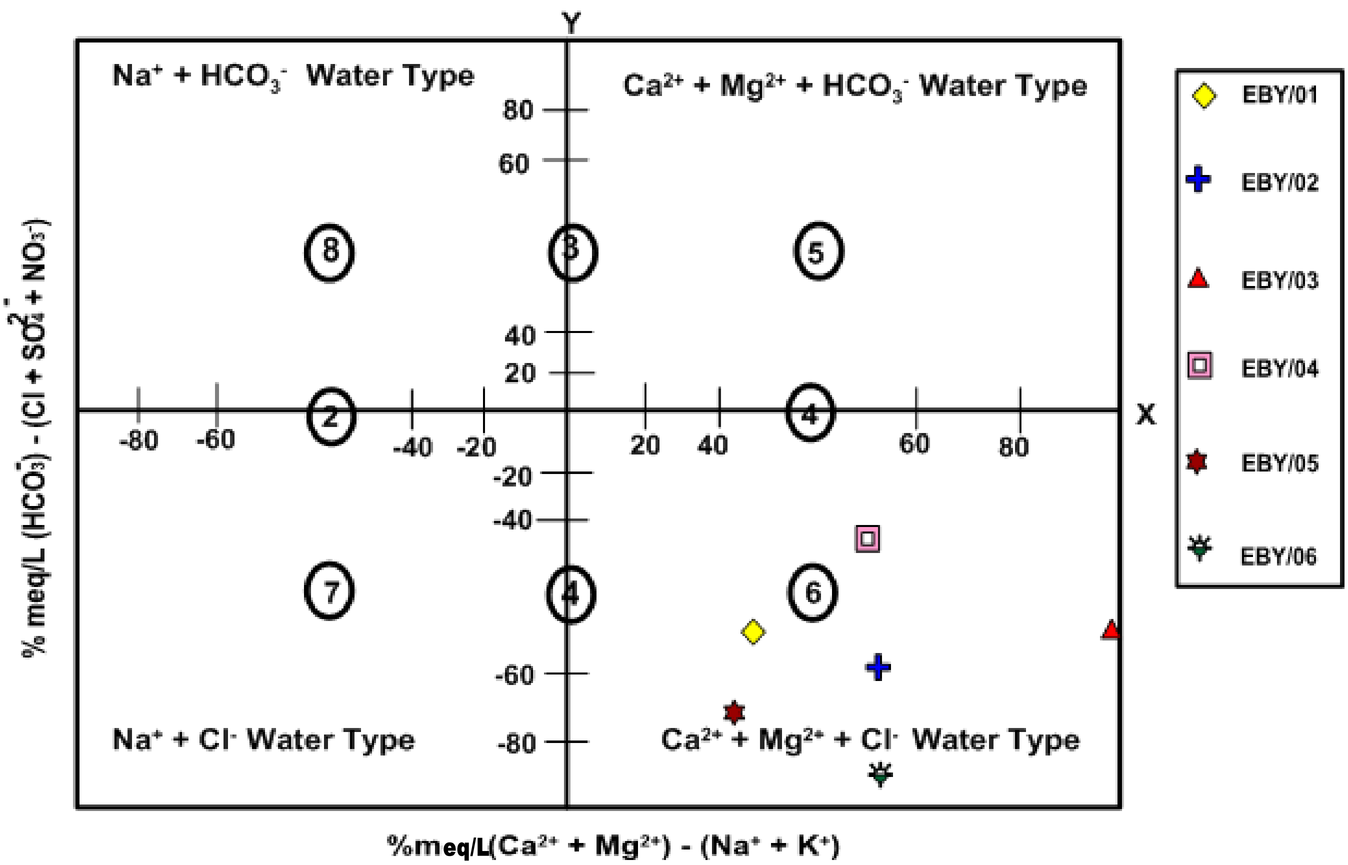

Figure 6: Chadha, (1999) Plot for Groundwater of the study area.

Groundwater is primarily govern lithology, nature of geochemical reactions and solubility of interactions rock. Gibbs, (1970) was of the view that dissolved ions can be broadly evaluated by plotting Na/(Na+Ca) aganist Cl/(Cl+HCO3). The Gibbs plot of data from study area (Fig.7) indicates that rock is the dominant processes controlling the major ion composition of groundwater.

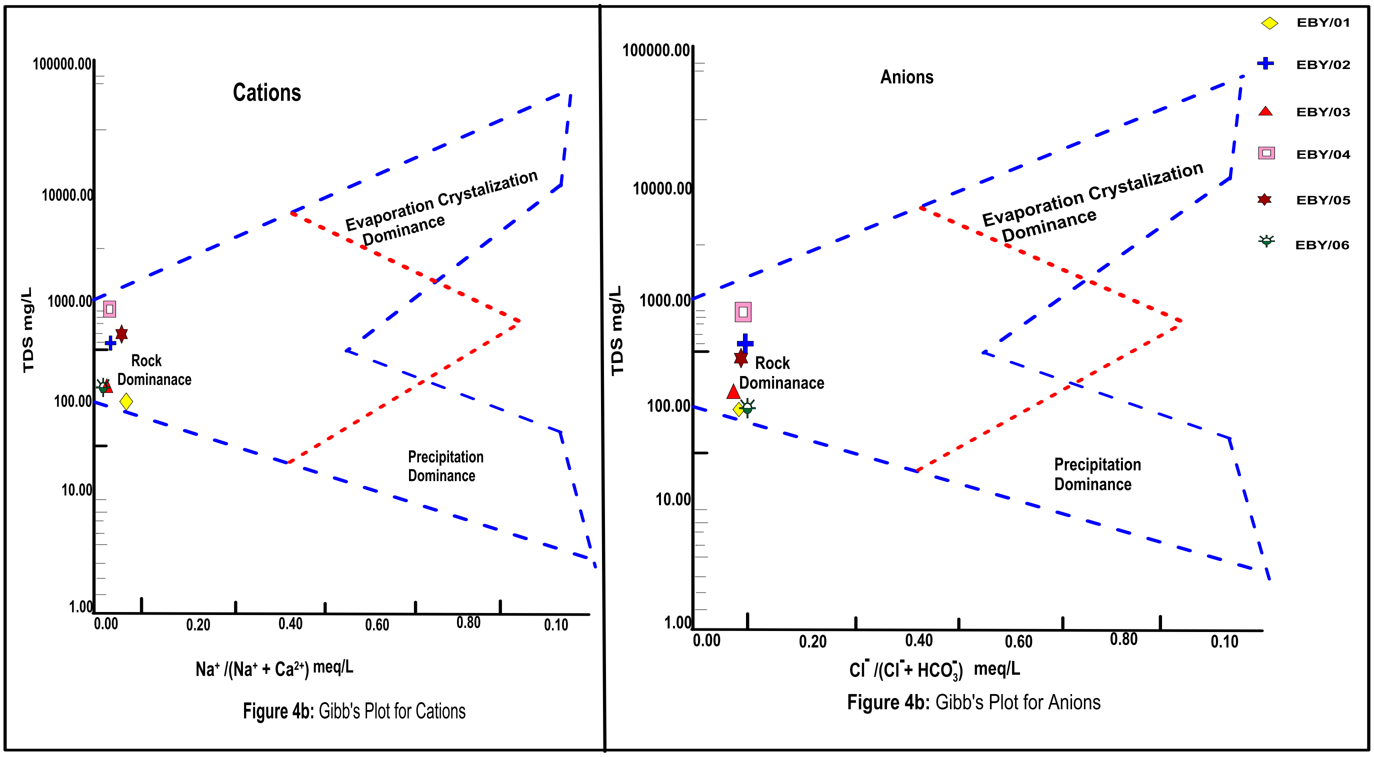

Figure 7: Gibb's Plot of Groundwater of the Study Area.

4. CONCLUSION

Findings from the study revealed that electrical conductivity ranges from (126.24 to 752.43 µS/cm), Total Dissolved Solid ranges from 90.32 to 855.27 mg L^{-1}, Total Hardness ranges from 41.00 to 95.00mg/L^{-1} SAR ranges from 0.28 to 0.78, MAR ranges from 11.7 to 536.8%, PI ranges from 0.40 to 1.00, KR ranges from 0.14 to 0.39meq/L, RSBC ranges from -1.43 to 0.6, Na% ranges from 14.00 to 39.02 %, SSP ranges from 0.28 to 0.78. Result from Piper and Schoeller diagrams revealed that sample EBY/01 is of Mg- Cl - HCO_3 water type, samples EBY/02 is of Cl - HCO_3, sample EBY/03 is of Mg- Ca –Cl water type, samples EBY/04, is of Ca-Na- Cl, sample EBY/05 is of Mg-Cl water type, while sample locations EBY/06 is of Ca-Cl. The dominat ionic species in the study area is Cl from the Piper plot. Based on the value of MAR sample locations EBY/01, EBY/ 02, EBY/03, EBY/03 is not fit for irrigation. While for sample locations EBY/04 and EBY/05 were considered suitable for irrigation. EBY/06 was considered fairly suitable for irrigation. Findings from Gibbs showed that rock water interaction is major process that influences groundwater.

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Conflict of Interest:

The authors declare that there are no conflicts of interests.

Peer-review:

External peer-review was done through double-blind method.

Data and materials availability:

All data associated with this study are present in the paper.

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